Ice-Based Thermal Energy Storage and LEED

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Benefits of Thermal Energy Storage

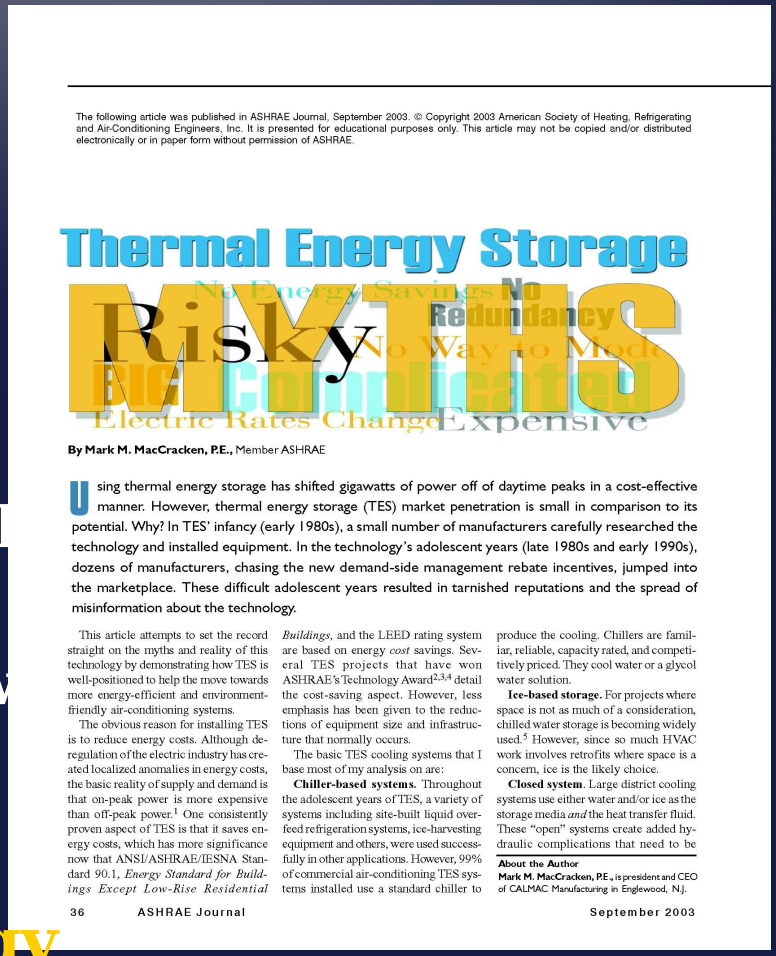
Reduces Peak Demand at most critical time	20-40%
Reduces first cost	up to 10%
Reduces consumer's energy costs	10-20%
Reduces energy usage at the building	up to 14%
Reduces source energy usage at power plant	8-34%
Reduces emissions	up to 50%
Provides operational flexibility	
Increases Load Factor of Generation	Up to 25%

Storage is a better way to add "Safety Factor" to your design

Thermal Energy Storage Myths Article
(Ashrae Journal Sept 03)

- 1. Uncommon
- 2. Too Much Space
- 3. Too Complicated
- 4. Doesn't Save Energy
- 5. Too Expensive
- 6. Lack of Redundancy (I
- 7. Rates Will Change
- 8. Modeling doesn't Show

Reality: TES is a Proven, Simple and Green Technology that saves Money and Energy



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Thermal Energy Storage

MYTHS

Risky

No Energy Savings

No Redundancy

No Way to Model

Big

Complicated

Electric Rates Change

Expensive

By Mark M. MacCracken, P.E., Member ASHRAE

Using thermal energy storage has shifted gigawatts of power off of daytime peaks in a cost-effective manner. However, thermal energy storage (TES) market penetration is small in comparison to its potential. Why? In TES' infancy (early 1980s), a small number of manufacturers carefully researched the technology and installed equipment. In the technology's adolescent years (late 1980s and early 1990s), dozens of manufacturers, chasing the new demand-side management rebate incentives, jumped into the marketplace. These difficult adolescent years resulted in tarnished reputations and the spread of misinformation about the technology.

This article attempts to set the record straight on the myths and reality of this technology by demonstrating how TES is well-positioned to help the move towards more energy-efficient and environment-friendly air-conditioning systems.

The obvious reason for installing TES is to reduce energy costs. Although deregulation of the electric industry has created localized anomalies in energy costs, the basic reality of supply and demand is that on-peak power is more expensive than off-peak power.[1] One consistently proven aspect of TES is that it saves energy costs, which has more significance now that ANSI/ASHRAE/IESNA Standard 90.1, *Energy Standard for Buildings Except Low-Rise Residential Buildings*, and the LEED rating system are based on energy *cost* savings. Several TES projects that have won ASHRAE's Technology Award[2,3,4] detail the cost-saving aspect. However, less emphasis has been given to the reductions of equipment size and infrastructure that normally occurs.

The basic TES cooling systems that I base most of my analysis on are:

Chiller-based systems. Throughout the adolescent years of TES, a variety of systems including site-built liquid overfeed refrigeration systems, ice-harvesting equipment and others, were used successfully in other applications. However, 99% of commercial air-conditioning TES systems installed use a standard chiller to produce the cooling. Chillers are familiar, reliable, capacity rated, and competitively priced. They cool water or a glycol water solution.

Ice-based storage. For projects where space is not as much of a consideration, chilled water storage is becoming widely used.[5] However, since so much HVAC work involves retrofits where space is a concern, ice is the likely choice.

Closed system. Large district cooling systems use either water and/or ice as the storage media *and* the heat transfer fluid. These "open" systems create added hydraulic complications that need to be

About the Author

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Thermal Energy Storage For Off-Peak Cooling

What is it?

How does it work?

Why is it Green?

Other “Green” Advantages

Storage is Natural part of almost any system

Most common TES System

4.5 kW Heater

Electric Water Heater

Assume one low flow showers running

((2.5gpm x 8.33 lb/gal x (110-60))

x 60 minutes/hr / 3,414 Btu/kWh = **18.3 kW each**

East Coast of US

100,000,000 people x 25% x 1/12 Hr/shower x 18.3

38 Gigawatts = CA Electric Peak on Summer d

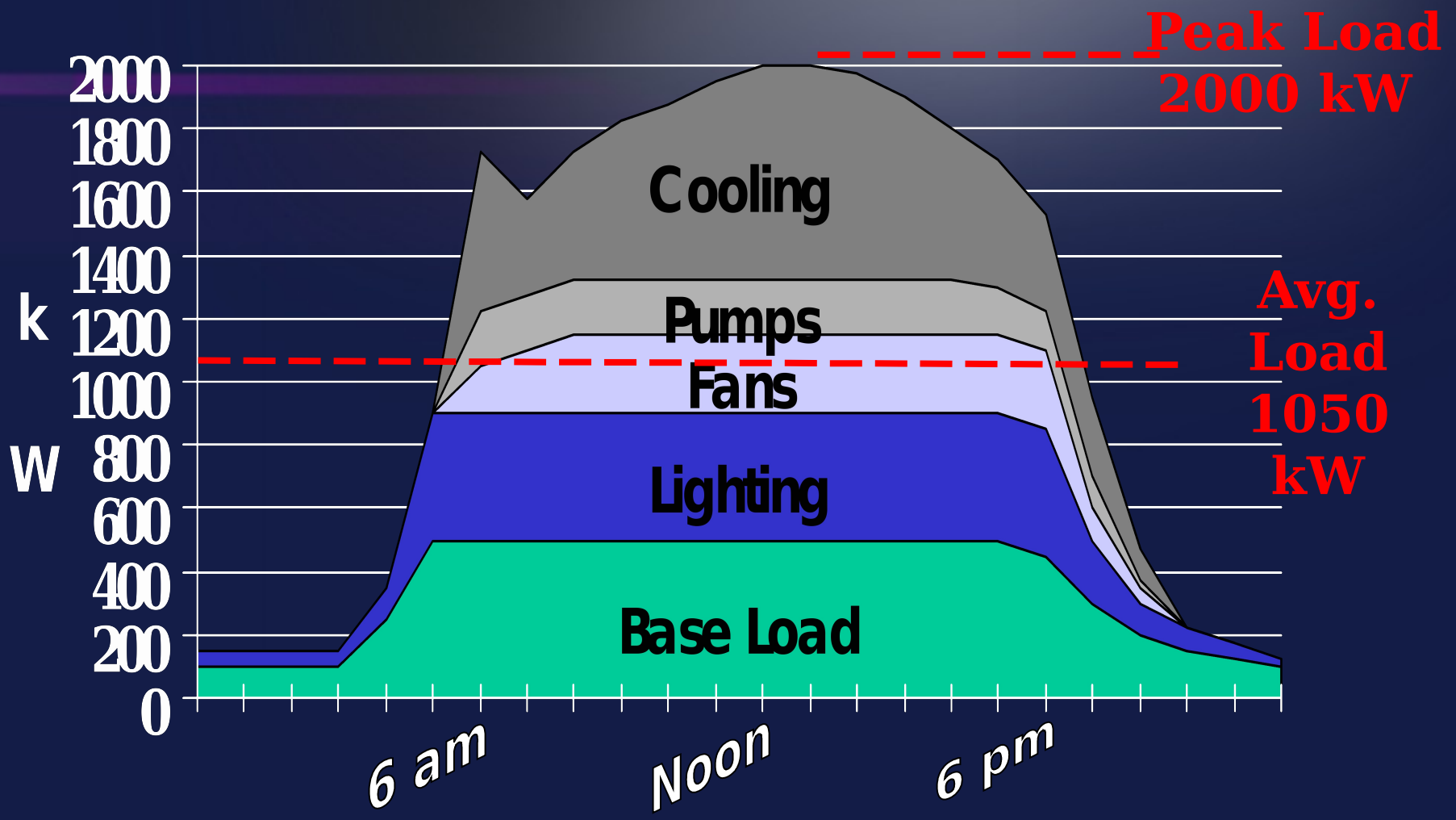
Gas Water Heater

Design Load = 2 Showers at a time

18.3 kW x 2 x 3414 = 124,950 Btus

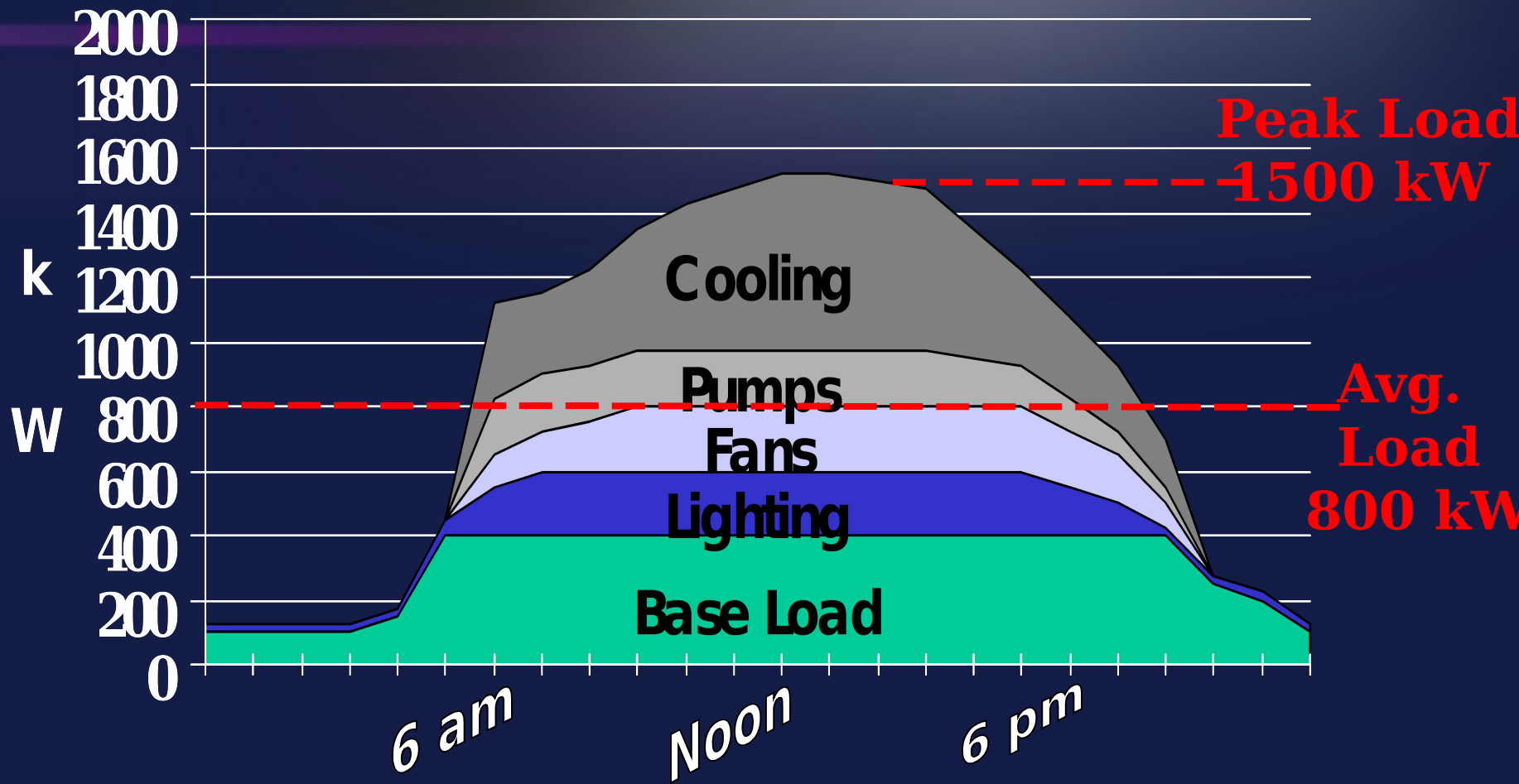
TES has already impacted US infrastructure

ASHRAE 90.1 Base Building Non-Storage Electrical Profile



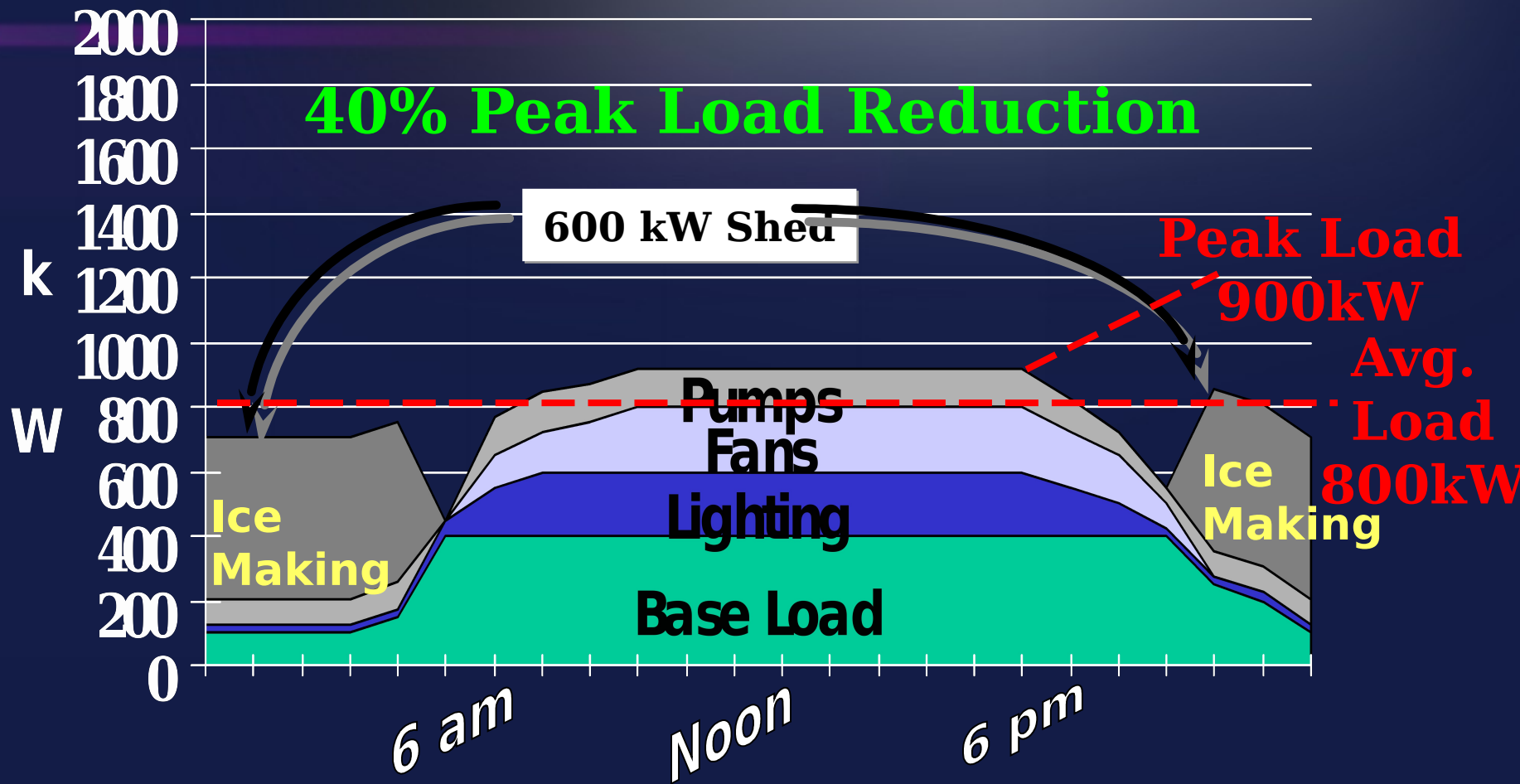
Total kWh = 28,000/day (Load Factor =

Design 30% better than 90.1%
Non Storage Electrical Profile



Total kWh = 19,200/day (Load Factor = 53%)

Off Peak Cooling (OPC) Electrical Profile



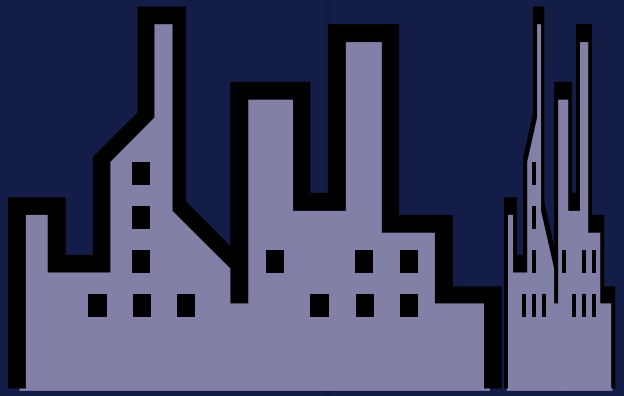
Total kWh = 19,200/day (Load Factor = 88%)

Power continue to be less expensive at Night because of Generation Load Factor

4 Buildings x 1 Megawatt

= 4 Megawatts

8,000 mW-h Sold



5 Buildings with TES @ 0.8 mW

= 4 Megawatts

10,000 mW-h Sold!

The same generator produces 25% more sellable kW-h!

Simple System.....

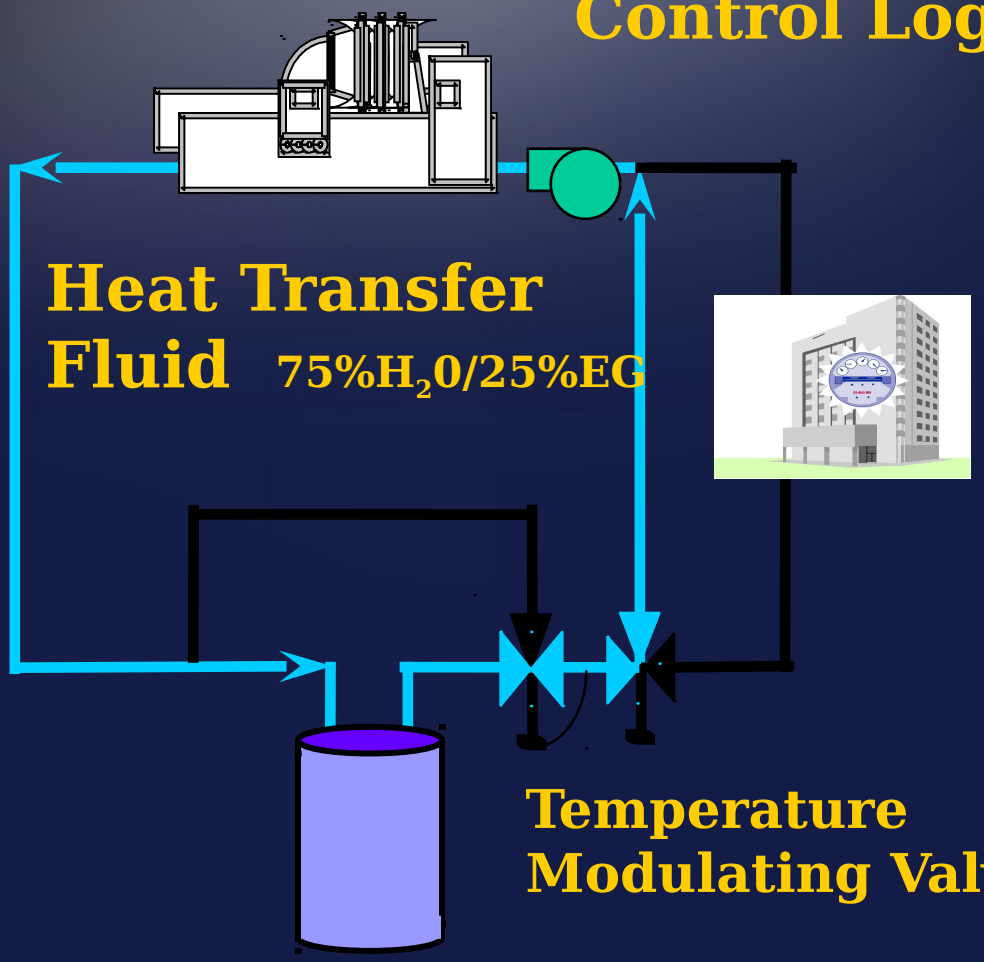
Almost like Non-Storage System

Control Logic

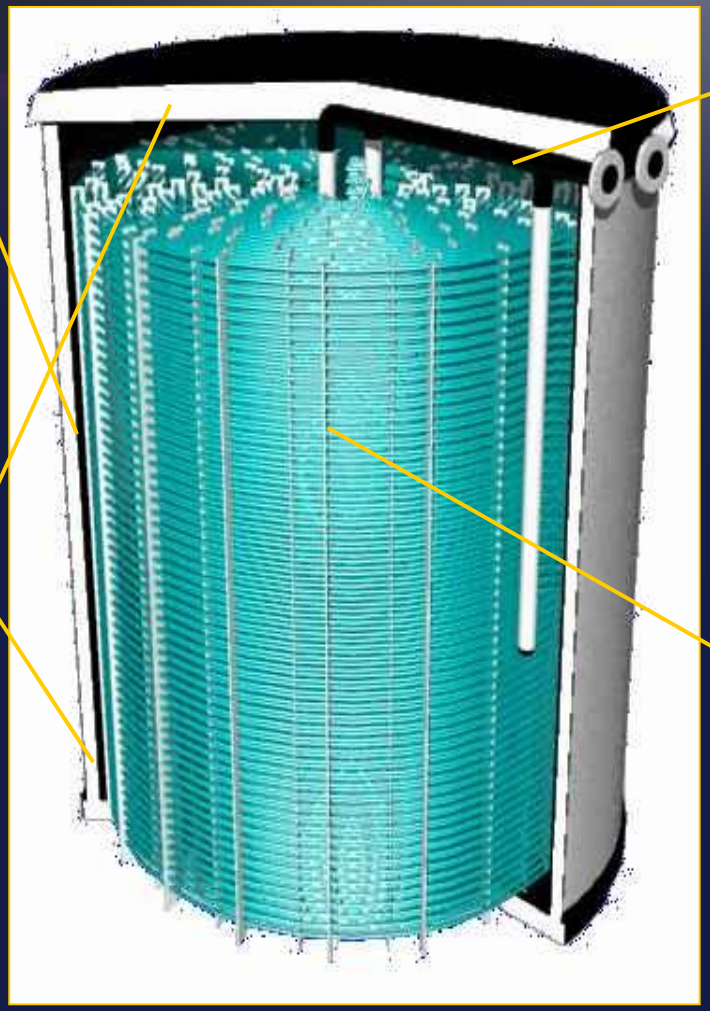
Chiller Based System

Closed System

So what is "Different"?



Thermal Storage Tank
Ice-on Coil, Internal Melt



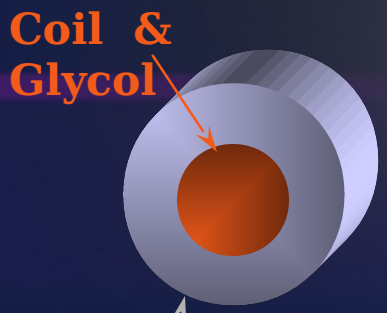
Tank

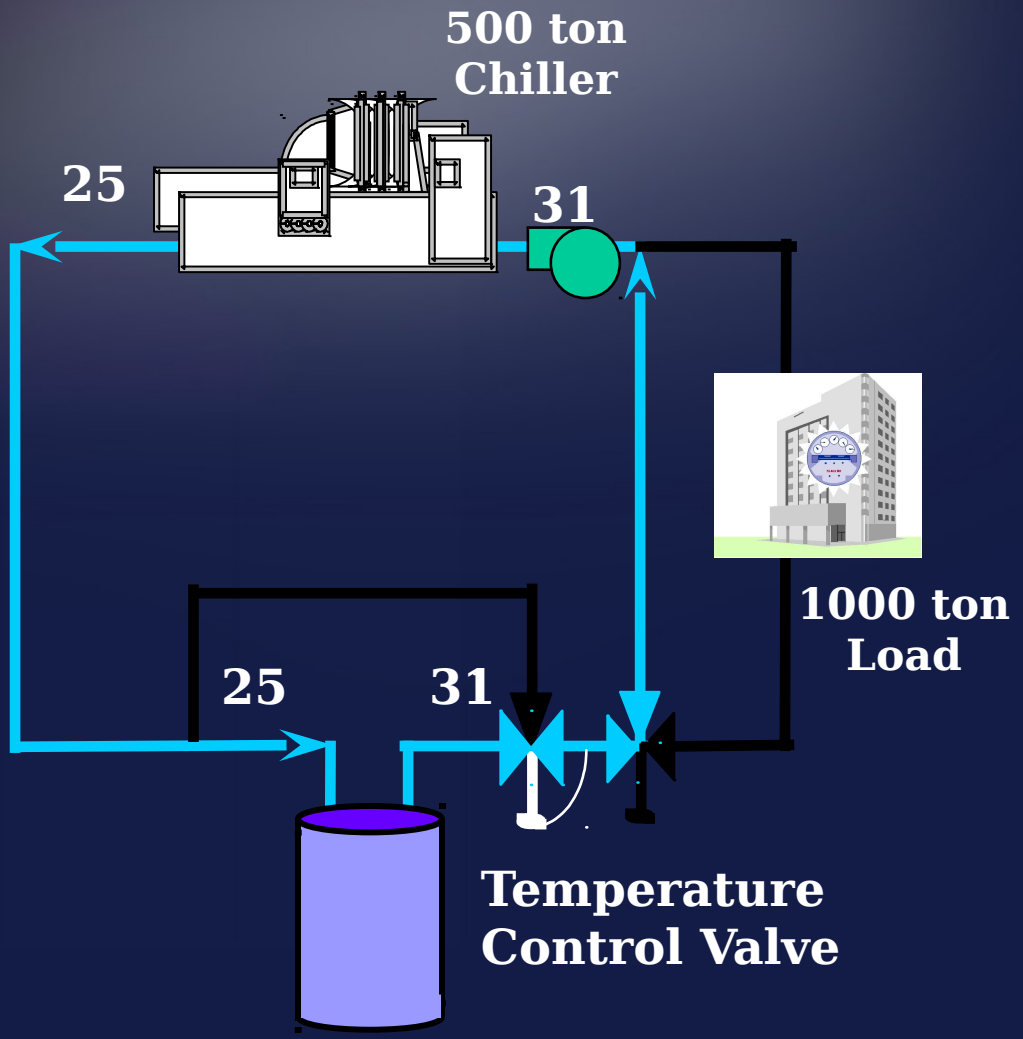
Insulation

Expansion Chamber

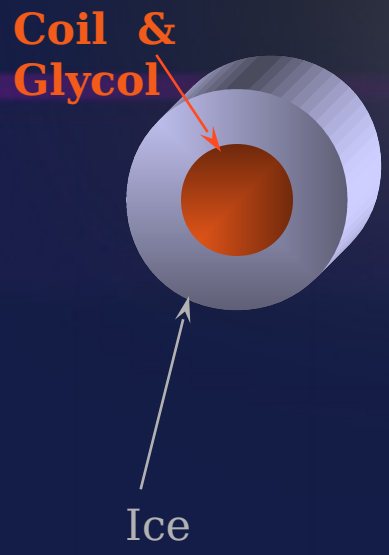
Heat Exchanger

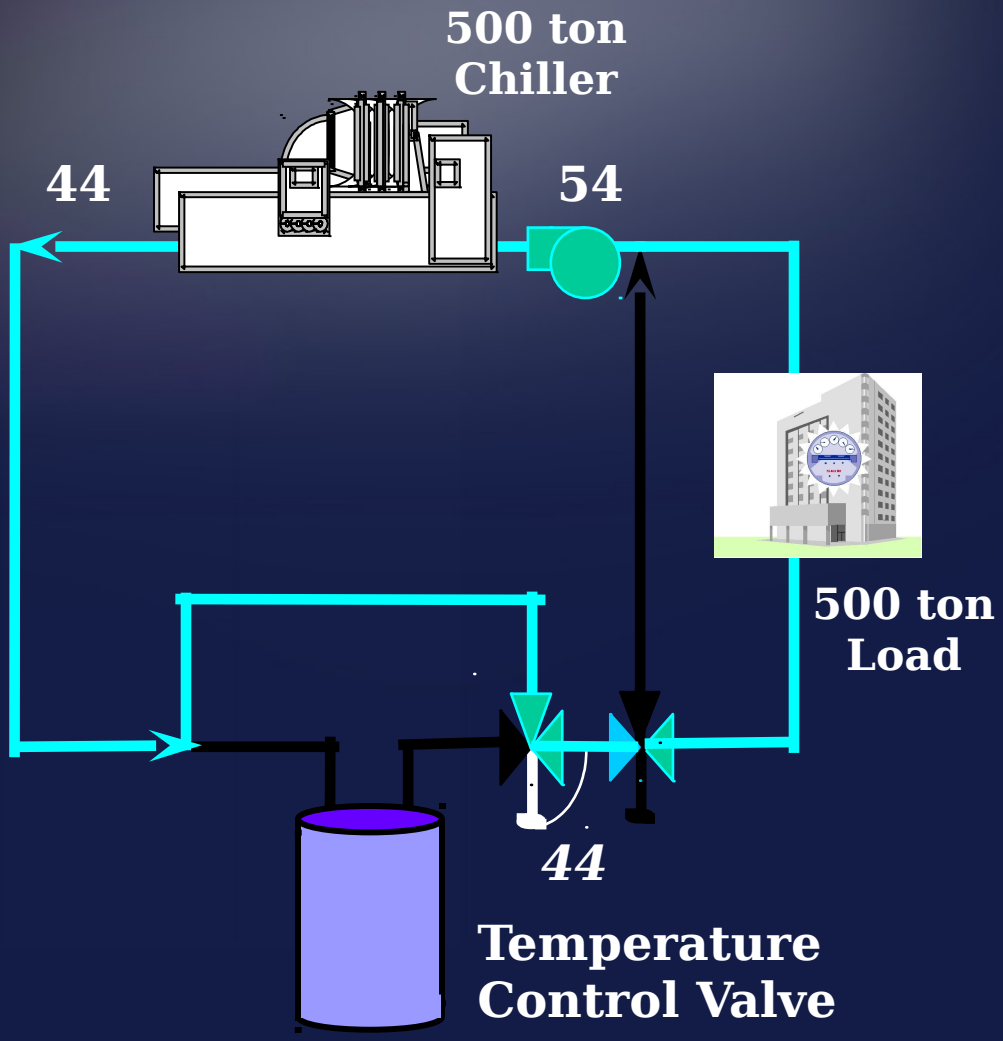
Ice Making (Off-Peak)



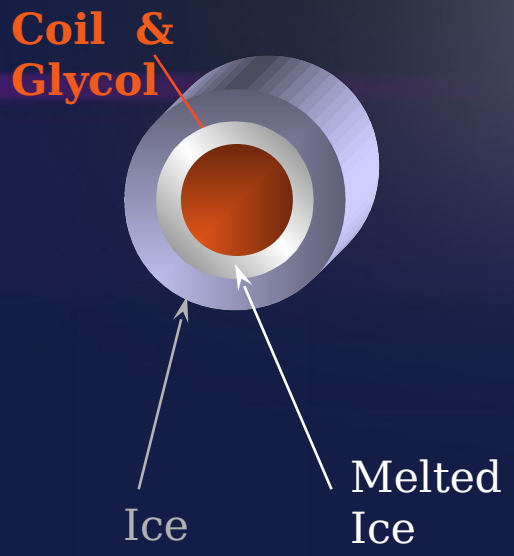


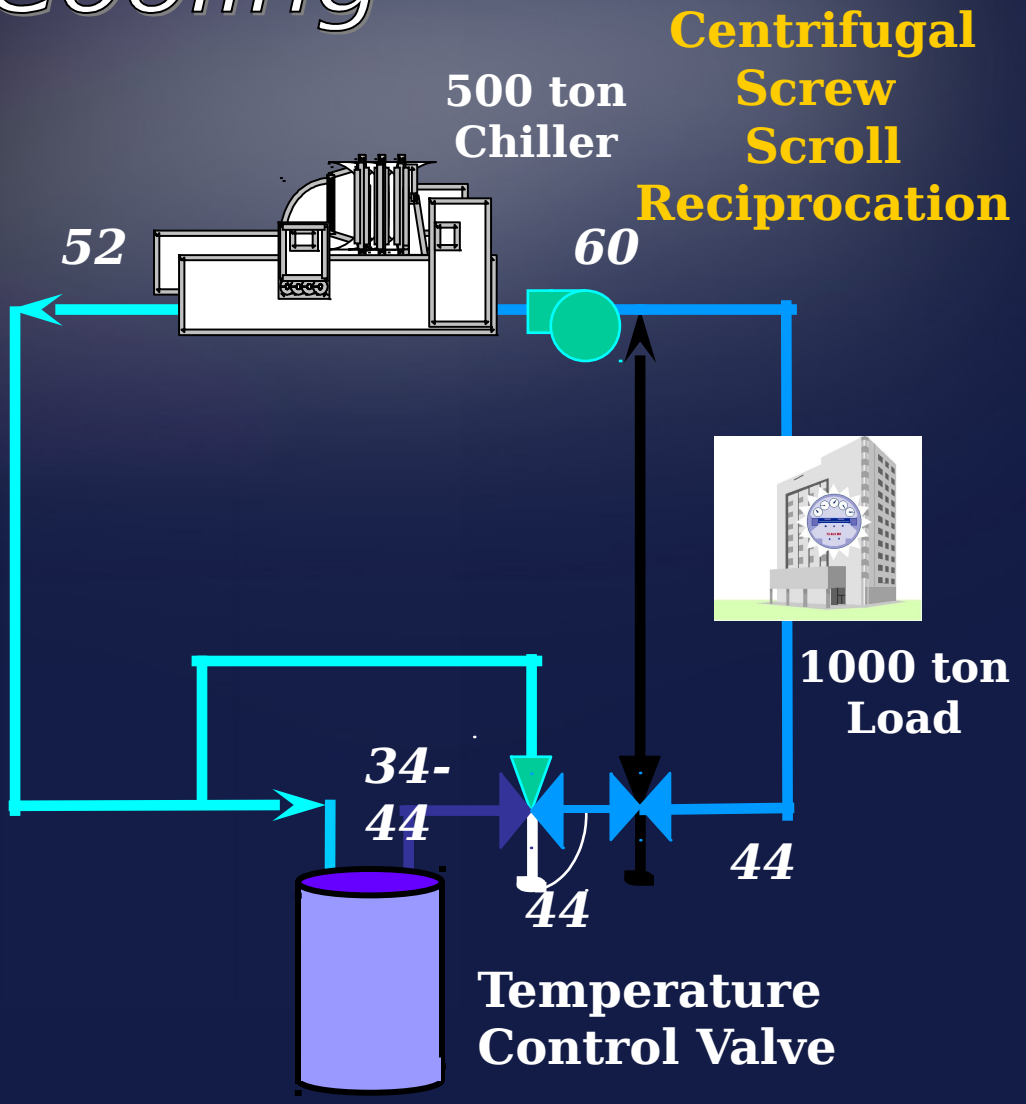
Direct Cooling





Ice and Chiller Cooling





Thermal Energy Storage For Off-Peak Cooling

What is it?

How does it work?

Why is it Green?

Other “Green” Advantages

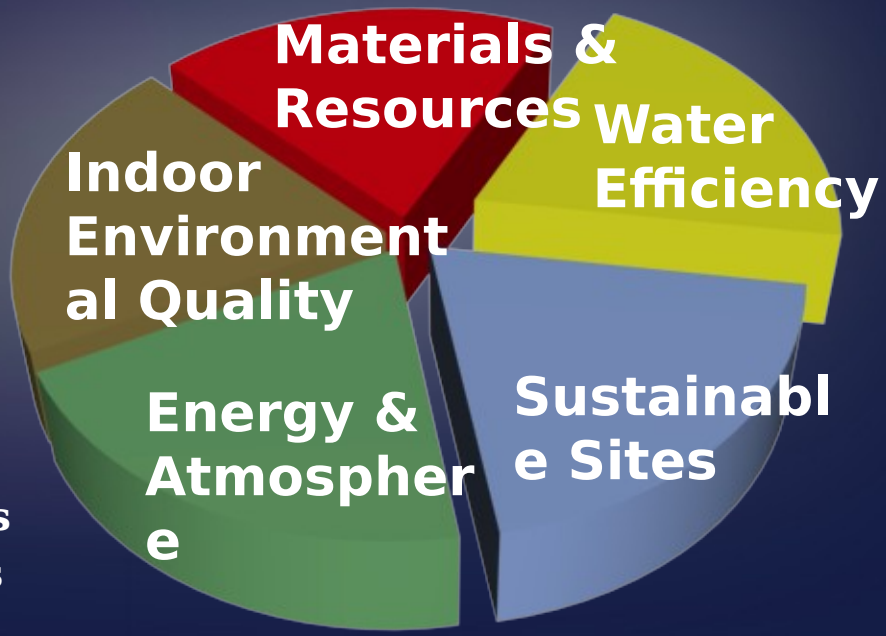
One Metric for “Green” is LEED

LEED™ Green Building Rating System

LEED

LEADERSHIP IN ENERGY & ENVIRONMENTAL DESIGN

LEED™ Credits



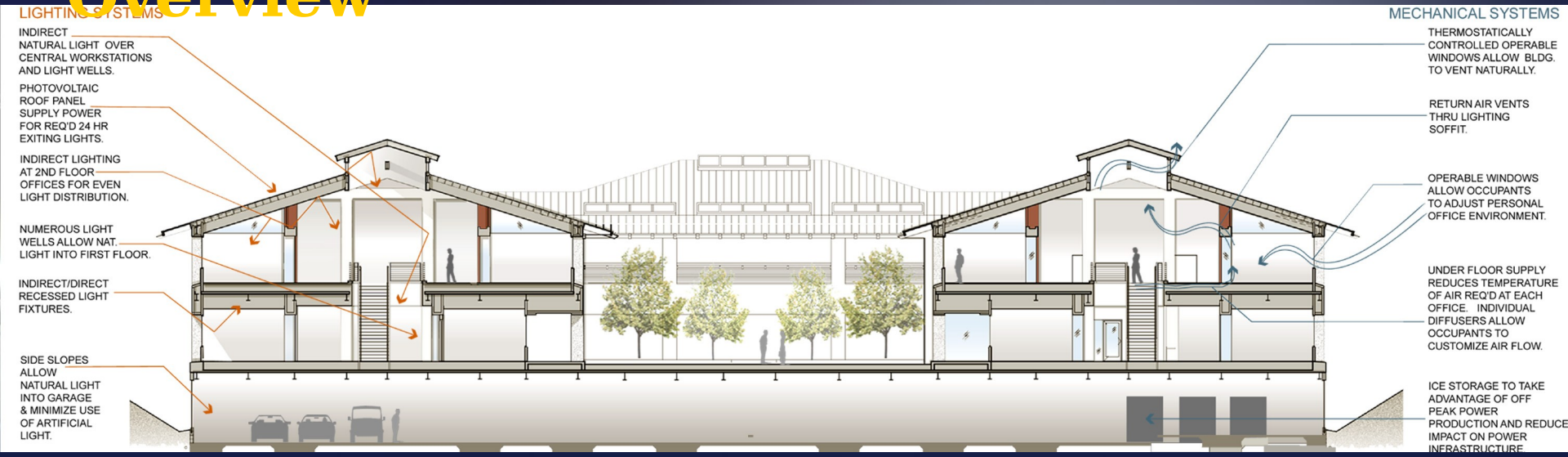
Sustainable Sites:	**14**	**points**
Water Efficiency:	**5**	**points**
Energy* & Atmosphere:	**17**	**points**
Materials & Resources:	**13**	**points**
Indoor Environment Quality:	**15**	**points**
Innovation & Design:	**5**	**points**

69 points

***10 Energy Credit are based on ASHRAE 90.1 which is based on Energy COST Reduction**

William & Flora Hewlett Foundation
LEED Gold
35% Energy Cost Reduction (5 points)

Project Overview

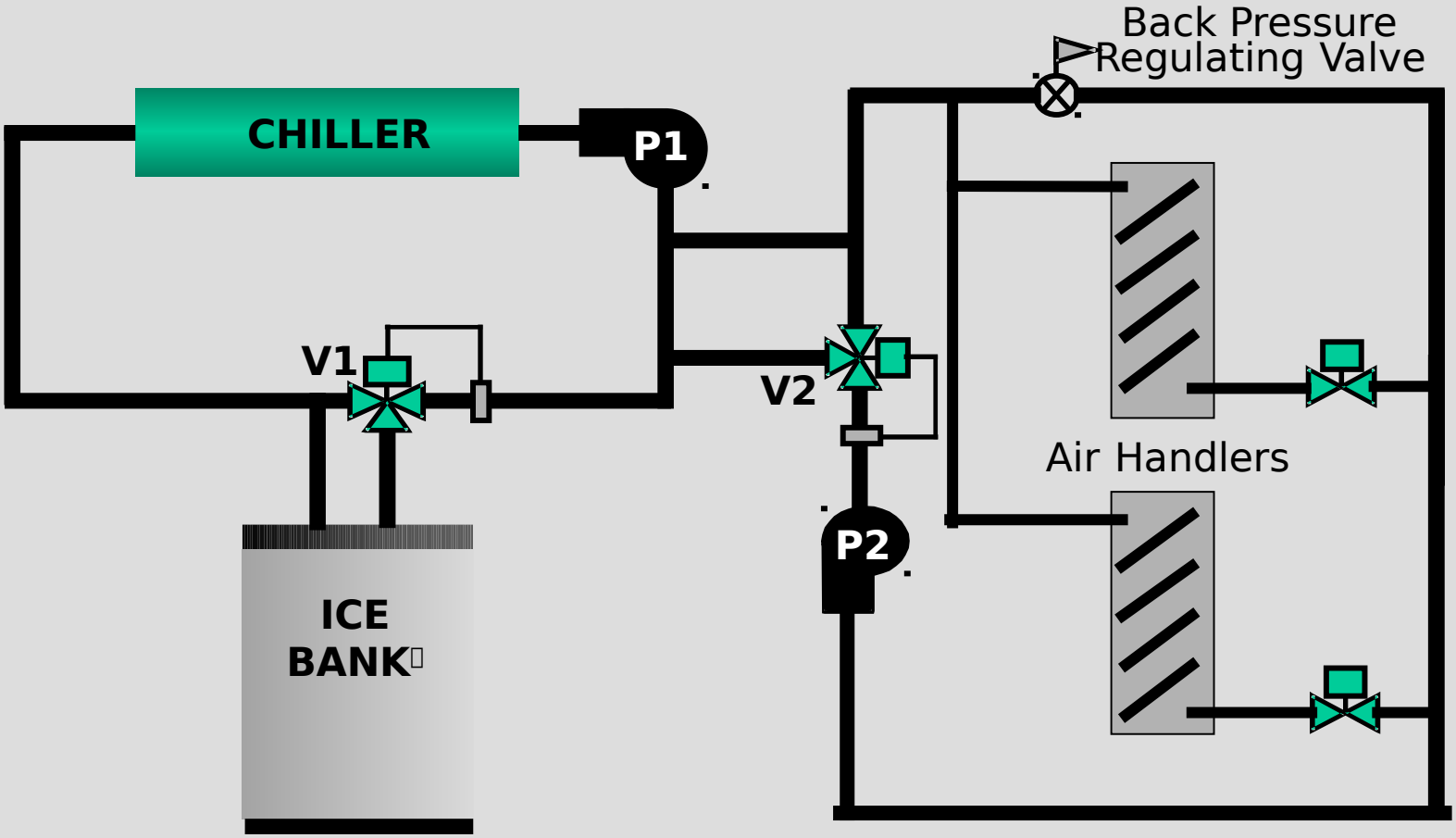

LIGHTING SYSTEMS
INDIRECT NATURAL LIGHT OVER CENTRAL WORKSTATIONS AND LIGHT WELLS.
PHOTOVOLTAIC ROOF PANEL SUPPLY POWER FOR REQ'D 24 HR EXITING LIGHTS.
INDIRECT LIGHTING AT 2ND FLOOR OFFICES FOR EVEN LIGHT DISTRIBUTION.
NUMEROUS LIGHT WELLS ALLOW NAT. LIGHT INTO FIRST FLOOR.
INDIRECT/DIRECT RECESSED LIGHT FIXTURES.
SIDE SLOPES ALLOW NATURAL LIGHT INTO GARAGE & MINIMIZE USE OF ARTIFICIAL LIGHT.
MECHANICAL SYSTEMS
THERMOSTATICALLY CONTROLLED OPERABLE WINDOWS ALLOW BLDG. TO VENT NATURALLY.
RETURN AIR VENTS THRU LIGHTING SOFFIT.
OPERABLE WINDOWS ALLOW OCCUPANTS TO ADJUST PERSONAL OFFICE ENVIRONMENT.
UNDER FLOOR SUPPLY REDUCES TEMPERATURE OF AIR REQ'D AT EACH OFFICE. INDIVIDUAL DIFFUSERS ALLOW OCCUPANTS TO CUSTOMIZE AIR FLOW.
ICE STORAGE TO TAKE ADVANTAGE OF OFF PEAK POWER PRODUCTION AND REDUCE IMPACT ON POWER INFRASTRUCTURE

- **External Shading**
- **Natural Lightening**
- **Operable Windows with Natural Ventilation**
- **Off –Peak Cooling system**

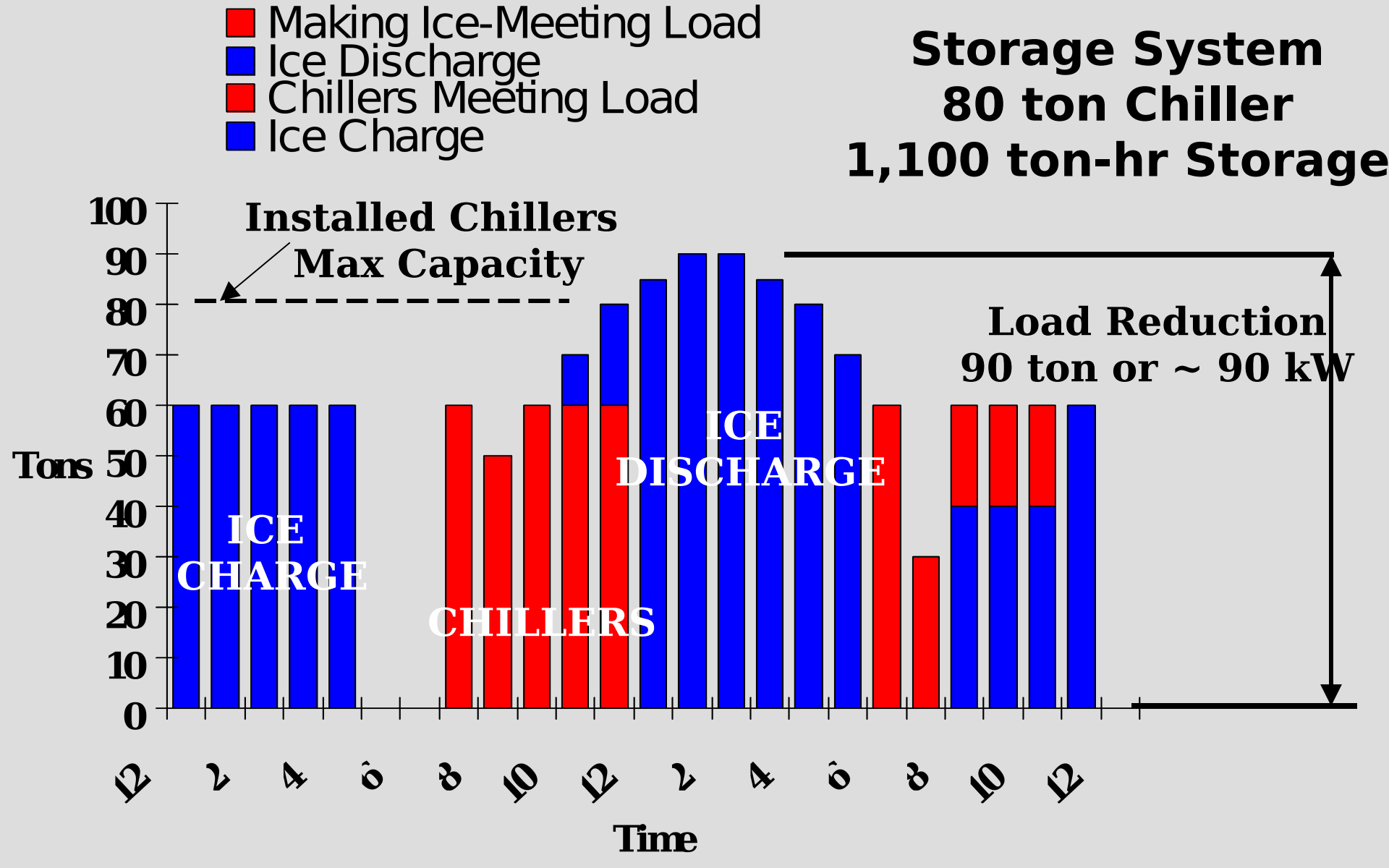
Basic Components
(Calculated 90 ~ 100 ton Peak Load)

80 Ton Evaporative
Condensing Chiller

1100 Ton-Hrs of Storage


Back Pressure
Regulating Valve
CHILLER
P1
V1
V2
Air Handlers
P2
ICE
BANK

Design Day Off-Peak Cooling System



Teamwork

- Owner
  The Hewlett Foundation
- Owner's Representative
  Bennington/Conover & Associates
- Shell Architect
  B.H. Bocook Architects
- Interior Architecture and Design
  Hawley Peterson & Snyder Architects
- Landscape Architect
  The Office of Cheryl Barton
- Contractor
  Vance Brown, Inc.
- Environmental Building Consultant
  Simon &

EPA/DOE Energy Star Building Label Program

- The Centex Building in Dallas Texas is the highest rated building with an unprecedented 99 out of 100 rating.
- It has the lowest Site Energy Intensity
- It has 2400 Ton-hr of Ice Thermal Storage and a water cooled screw chiller.

(www.energystar.gov)

Would qualify for 10 pts. in new LEED EB Rating System for Existing Buildings

Real reasons Off-Peak Cooling Green:

1. **It is much more Energy Efficient to create and deliver a kWh of Electricity at night then during the hot of the day.**
   - Research from the California Energy Commission on 2 Cal. Utilities Reports 8 to 34% savings in raw fuel when comparing On and Off Peak Operation!
   - Heat Rates for Base Load Plants ~8,700 Btu/kWh vs. Peaking Plants ~9,400 to 11,600 Btu/kWh
2. **The last power plants to come on during peak hours are normally the dirtiest per kW**
   - Ashok Gupta (Director of Energy, NRDC) in NYTimes article "Peak Shifting results in lower emissions because some of the plants used to meet demand peaks are among the dirtiest in the city"
   - New CA Report by Greg Kats *The Costs and Financial Benefits of Green Buildings* states Peak power in CA is twice as dirty as Off Peak Power.

Thermal Energy Storage For Off-Peak Cooling

What is it?

How does it work?

Why is it Green?

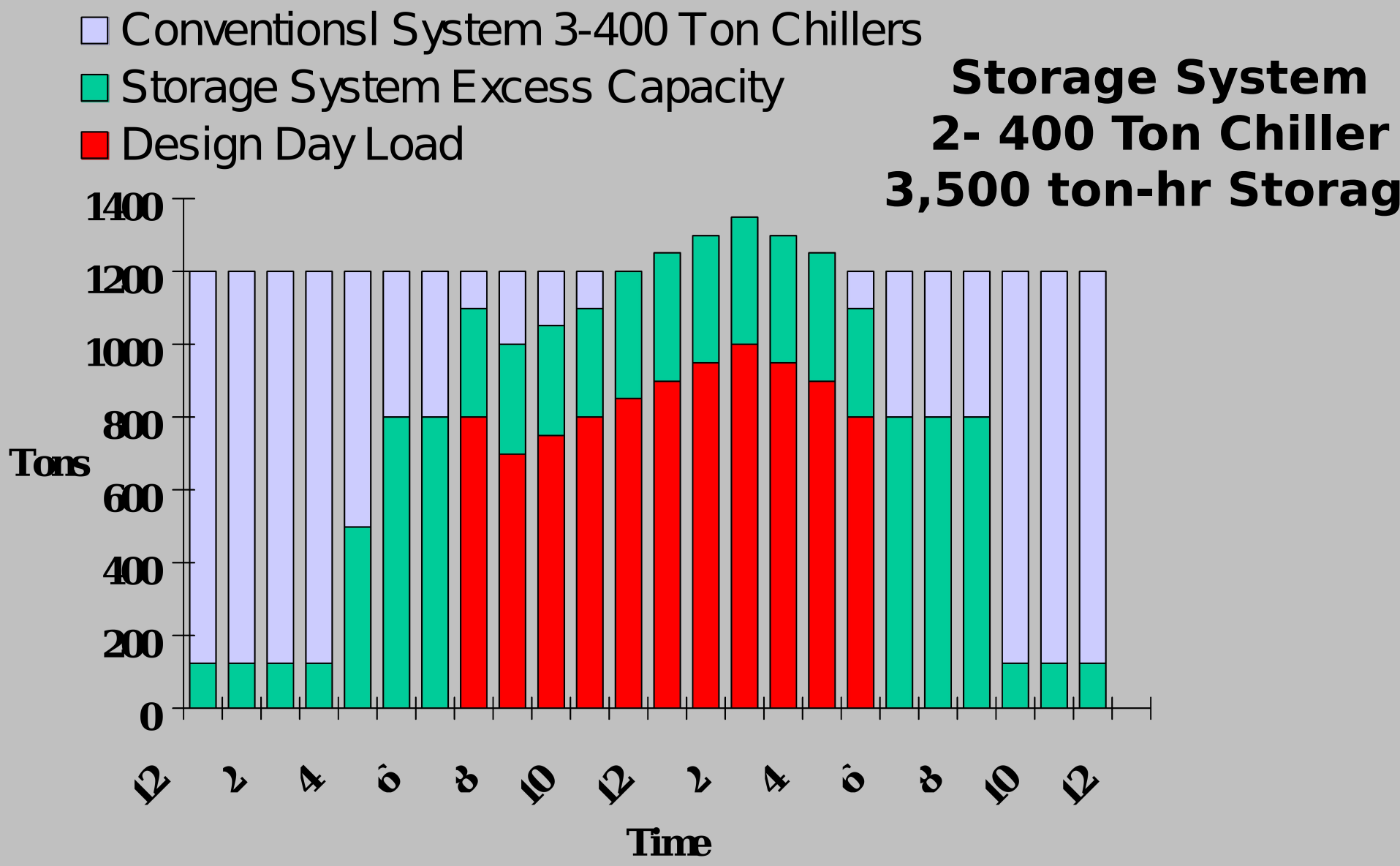
Other “Green” Advantages

Other “Green” Issues

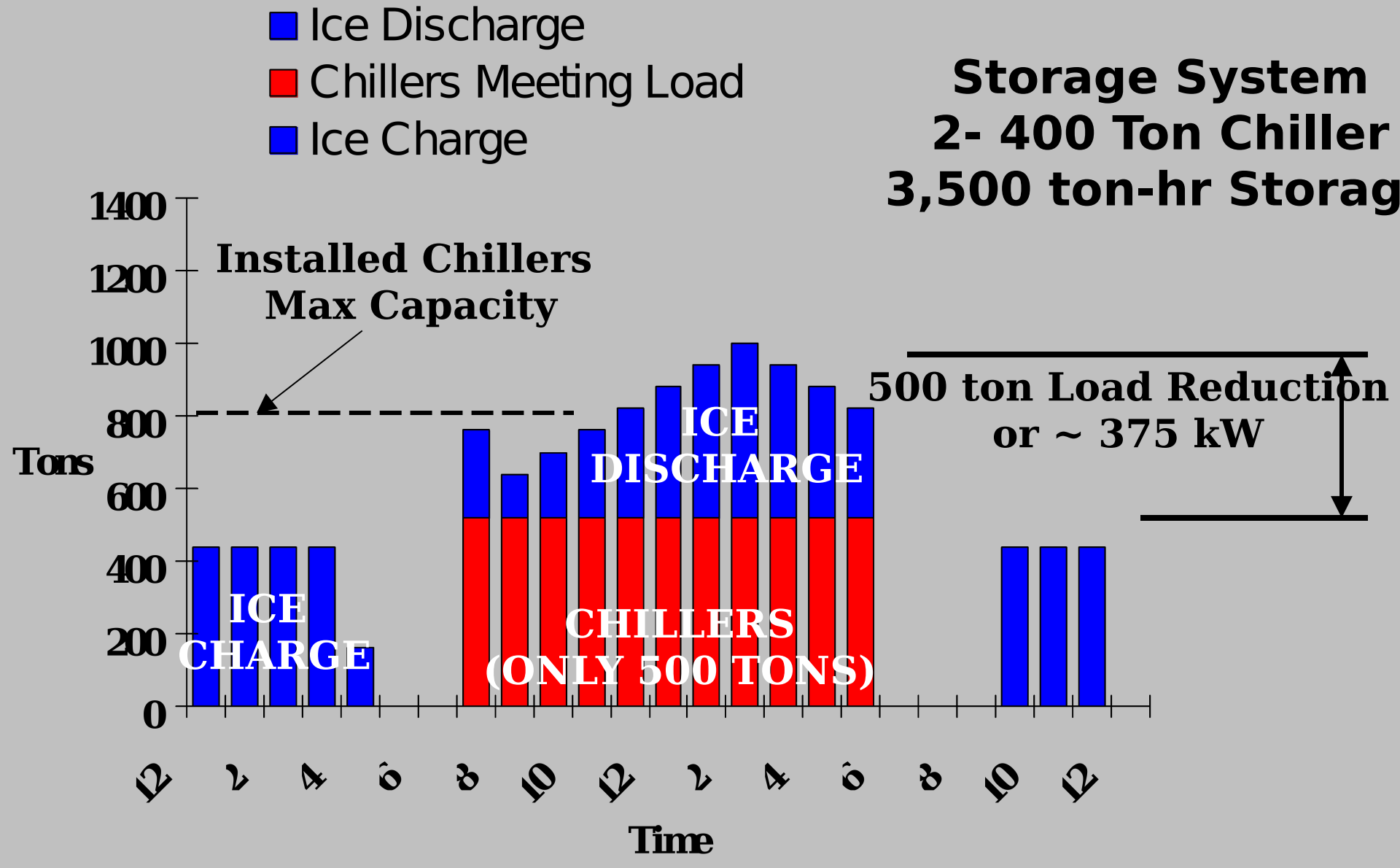
1. Safety Factors (Oversizing)
   - Well documented that oversizing chiller plants creates less efficient real world operation.
   - Engineers have to protect their license

Storage is the Natural solution to this Rock-and-a Hard Place dilemma

Safety Factor Without Oversizing for same Cost



Design Day Off-Peak Cooling System



Capacity on Design Day with One Chiller Failure

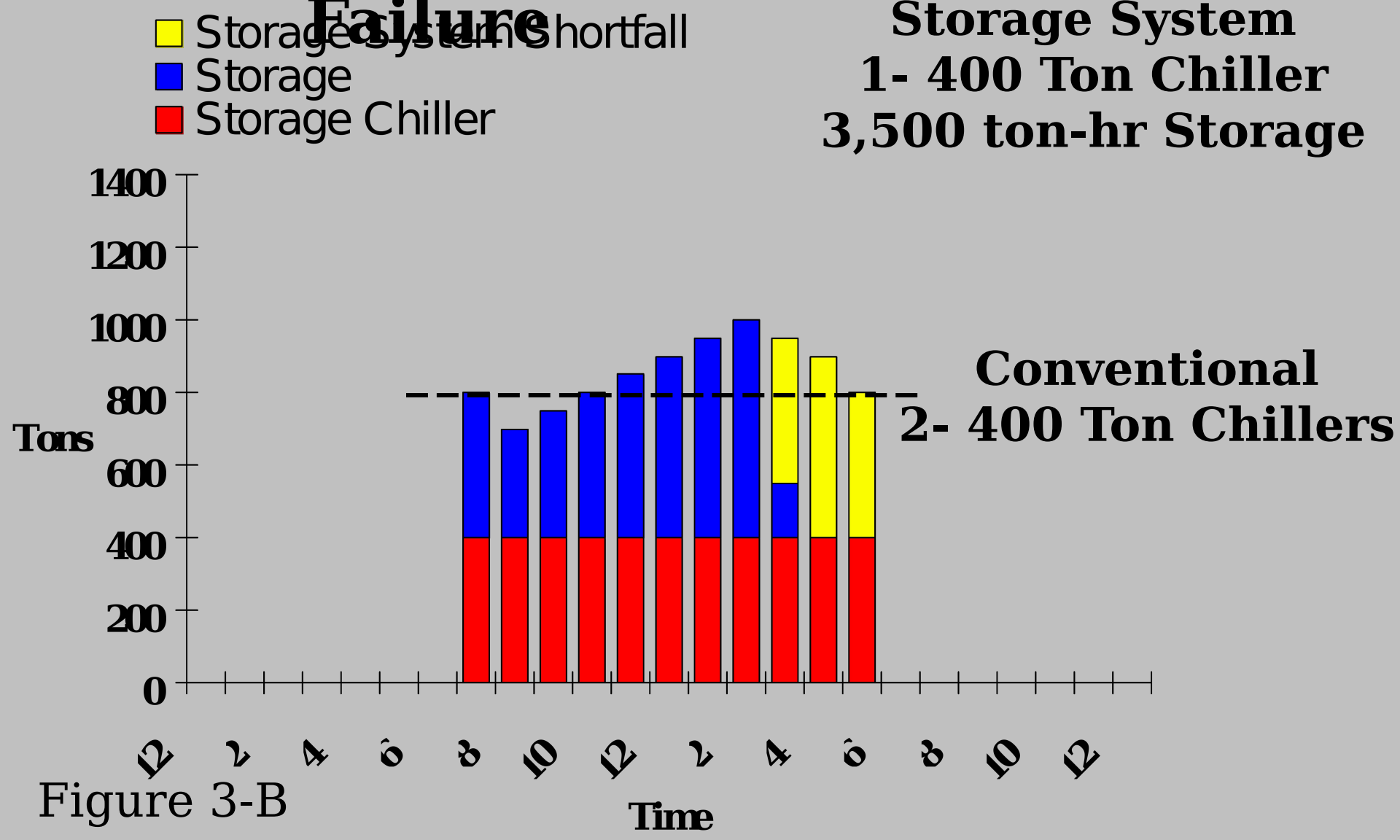


Figure 3-B

Installed Cost Summary-1000Ton Peak with Back-Up Gen

Non-Storage System 3-400 ton Chillers, 750 kW Peak*
Storage System 2- 400 ton Chillers, 3,500 ton-hr Ice Storage, 375 kW Peak* Reduction

	$/ton	$/ton Hr	$/ Peak kW	Non- Storage System Cost	Storage System Cost
Chillers	$900			$1,080,000	$720,000
Storage (8.75 ton-hr/ton)	$875	$100	$875		$350,000
Sub Total Chiller Plant Cost				$1,080,000	$1,070,000
Less 375 kW* Back-Up Generation			$1000	-	(-$375,000)

*Approximation includes Chiller and all ancillary po

Demand Charge Effect…..Do the Math

Rate = $0.05/kW-h and $10/kW

Conventional Chiller System

Demand Cost /month

100 tons x 1.0 kW/ton = 100 kW

100 kW x $10.00 = $1,000 month/100 tons

Energy Usage for Chiller for Month

100 tons x 12 Hrs x 75% x 1.0 kW/ton x 22 days/month = 19,800 kWh

Approximate Cost for Demand / kWh

$1,000. /19,800 kWh/month = $0.051 / kWh

Actual Cost per On-Peak = $0.05 + $0.051 = $0.101 / kWh

Actual Off Peak = $0.05 / kWh

Other “Green” Issues

1. Safety Factors (Oversizing)
   - Well documented that oversizing chiller plants creates less efficient real world operation.
   - Engineers have to protect their license

Storage is the Natural solution to this Rock-and-a Hard Place dilemma

2. Efficiency and Water Use
   - Electric Chillers
   - Absorption Chillers

Chiller Energy and Water Efficiency Comparison

Chiller Type	"Site" COP	EER	KW/Ton	Source Energy COP*	Site Heat Rejection Factor	Water Use Increase
Electric Centrifugal	6.0	20.5	0.58	2.00	1.17 14,000 Btu/ton	---
Electric Screw or Centrifugal Making Ice	5.0	17.1	0.70	1.66	1.20 14,400 Btu/ton	3%
Electric Scroll	4.0	13.6	0.88	1.33	1.25 15,000 Btu/ton	7%
Absorption (Double Effect)	1.2			1.20	1.83 22,000 Btu/ton	57%
Absorption	1.0			1.00	2.00	71%

*Assumes 33% National Electric Grid Efficie

Federal Projects

Moorhead Federal - Pittsburgh
Federal Court House - Boston
Miramar AFB MCAS Bldg. - San Diego, CA
Marine Corp. Air Station, Yuma, AZ
McClellan AFB - CA
Edwards AFB - CA
Third District Court, Miami, FL
US Coast Guard, Baltimore, FL (4) Projects
Fort Meade, Ft. Meade MD (2) Projects
US Army Reserve Center, Toledo, OH
Fort Eustis, Ft. Eustis, VA, (5) Projects
Kuala Lumpur US Embassy Bldg.

Moorehead Federal Building, Pittsburgh PA

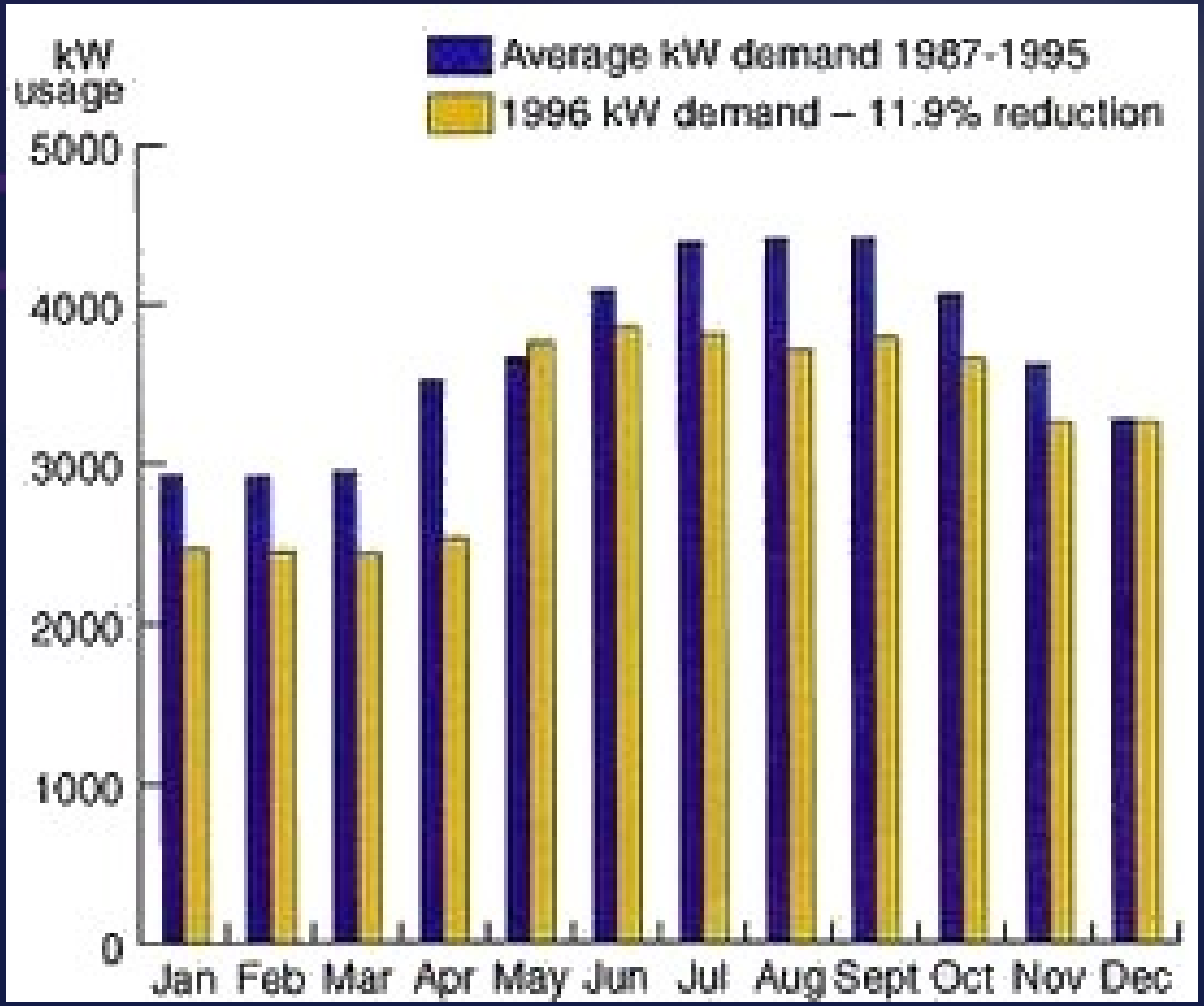
Old

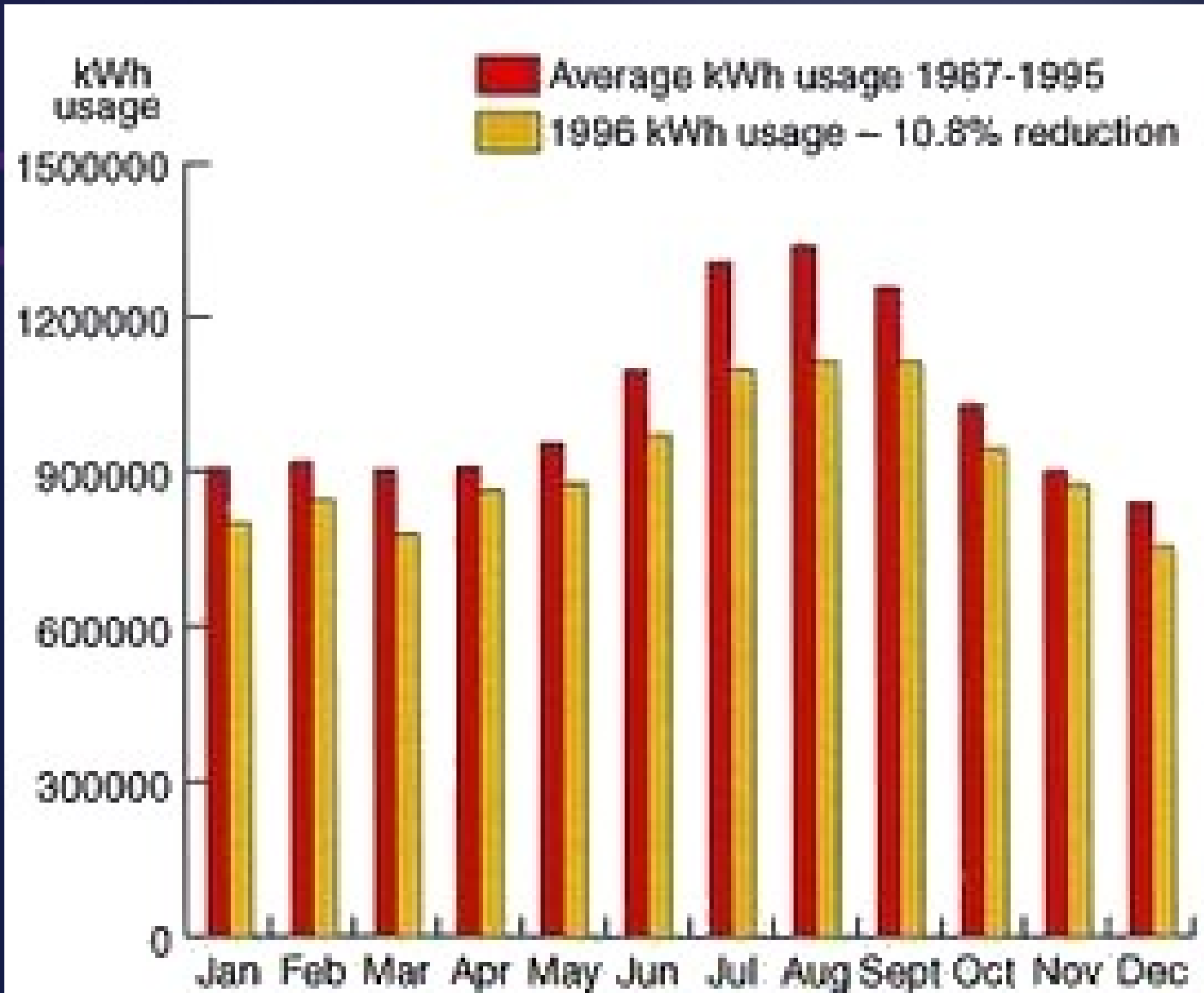
2-900 ton chillers, 0.9 kW/ton

New

2-660 ton, 0.6 kw/ton

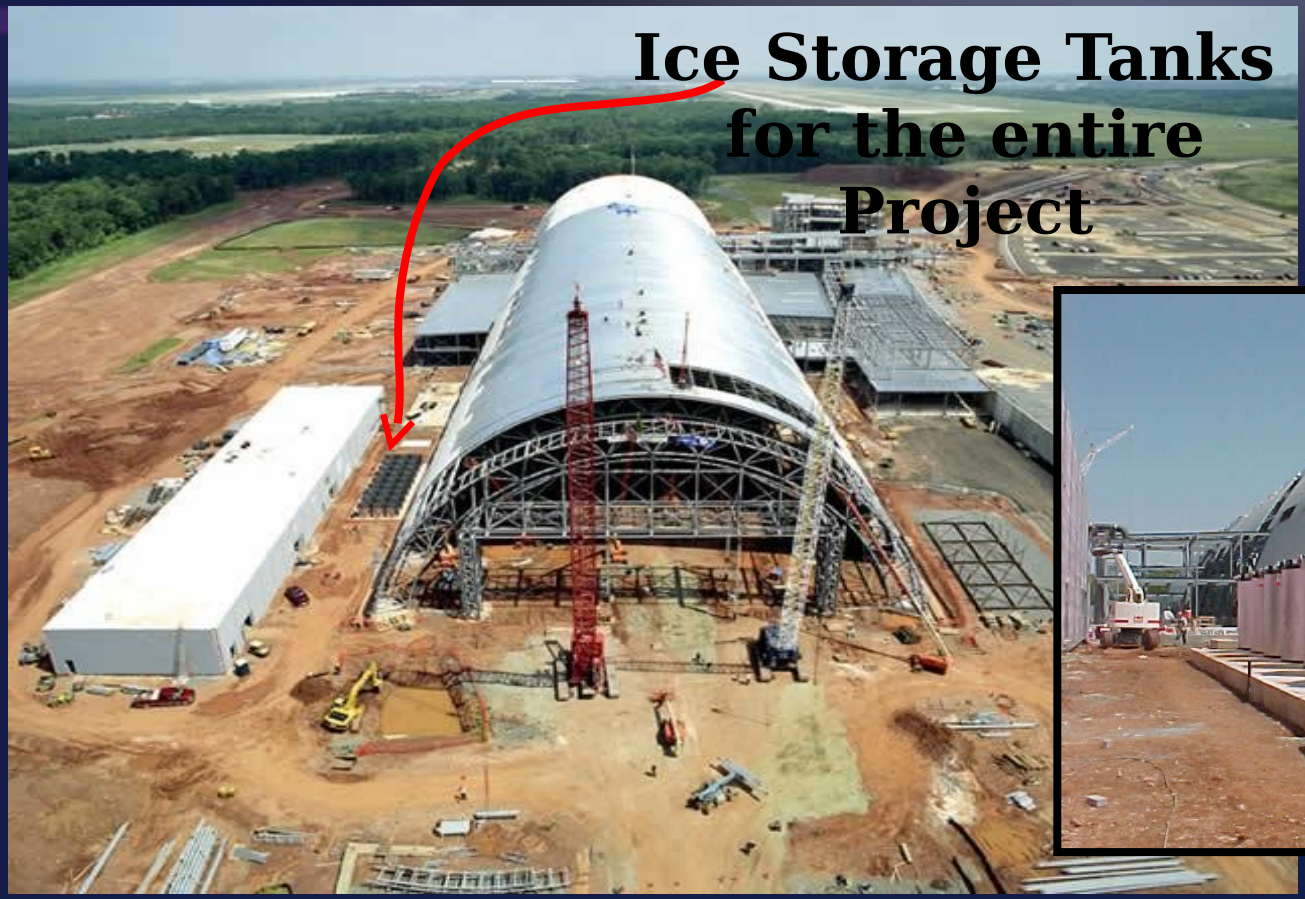
6240 ton-hr Storage


kW usage
Average kW demand 1987-1995
1996 kW demand – 11.9% reduction
5000
4000
3000
2000
1000
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sept
Oct
Nov
Dec


kWh usage
Average kWh usage 1967-1995
1996 kWh usage – 10.8% reduction
1500000
1200000
900000
600000
300000
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sept
Oct
Nov
Dec

National Air and Space Museum, Washington, DC USA

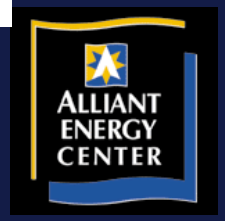
4,700 Ton Hrs of Storage
On-Peak Chiller – 1122 Tons
On-Peak Ice Contribution – 729 Tons
40% On-Peak Chiller Demand Avoided



UL
8,000 Ton-Hr
2.5 days to install

Costco Projects
3 in Japan
2 in Korea
2 in USA

TES… in over 6000 installations in 35 countries, many installed over 20 years ago



Conclusions:

Storage is Nature's Safety Factor

Engineer's Paradigm must change.

- **Instead of adding 20-30% to estimated Load, reduce by 20-30% and add Storage for Safety at no extra Cost.**

Cool Storage reduces

- **Operating Costs**
- **Load on Grid**
- **Impact on Environment**

Union County Votech